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ABSTRACT

This report summarizes the results of more than 10,000 individual judgments, carried out in five related studies, all concerned with perceived reading efforts of text on visual displays and printouts. Students and personnel in the Department of Computer Science at the University of Stockholm served as study subjects. In experiments in which stimulus materials were real texts with similar context (lists of names and addresses), subjects were shown stimuli at random and were asked to judge their perceived reading efforts according to a five grade verbal rating scale: very great effort, great effort, neither great nor little effort, little effort, and very little effort. Methods and results of the five studies are presented in three categories: color of text and background; context colors; and printouts (from eight different printers). Five tables and a four-item bibliography support this report. (THC)

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Rune Pettersson

Reading Efforts on Visual Displays

Theme Report No. 20
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Reading Efforts on Visual Displays

This report summarizes the results of more than 10.000 individual judgements, carried out in five related studies, all concerned with perceived reading efforts of text on visual displays and print outs.

In all experiments the stimulus materials have been real texts with similar context, lists of names and addresses, showed to the subjects at random. All subjects have been students and personnel at the department of Computer Science at the University of Stockholm. The subjects judged their perceived reading efforts according to a five grade verbal rating scale: very great effort, great effort, neither great nor little effort, little effort and very little effort. The scale also ranges from 0 to 100. Hence a good combination e.g. of text and background colors has a high value, while bad combinations have low ones.

Color of text and background

In the first study "Color Information Displays and Reading Efforts" (Pettersson et.al. 1984), 40 subjects judged the aesthetic values of twelve colors and thereafter judged the perceived reading efforts of the possible 132 color combinations.

The combination of various software and the CLEA technical equipment, a Cromemco microcomputer, a Scion Micro Angelo Color subsystem and an interfaced digitizer, allowed the researchers to "simulate" any kind of actual equipment. However, in this study strong efforts were made to relate and define the color stimuli used in the experiments to the Natural Color System. The colors as well as the color combinations were shown at random. All experiments were conducted in a controlled "daylight-working-situation", which might be very different from other experimental situations conducted in a variety of contexts.

The context in which a message is presented play a major role with respect to our perception of the message. E.g. in some studies, different displays have been used for different subjects.

The study can be concluded in the following points:

1. Colors presented on color displays seem to be ranked in the same order as surface colors in traditional print media. Blue was most popular.

2. When text is shown on a visual display there is no color combination which requires very little reading effort and thus is very easy to read. From 132 combinations about 35 are acceptable. Most combinations are bad.

3. The best text color is black, which cause good contrast to most background colors.

4. The best color combination is black text on a white or yellow background.

5. A text can be easy to read in any color, provided the background is carefully selected.

6. The best background color is black, which has good contrast to most text colors.

7. Reading efforts of color combinations are independent of the sex of the subjects.

For details regarding p. 2-6 please see Table 1.

Table 1. Judged perceived reading efforts, mean values, all subjects (high values = good combinations, low values = bad combinations).

Background	Text											
	Whi	Gry	Bla	Bro	Yel	Y-R	Red	R-B	Blu	B-G	Grn	G-Y
White	-	68	76	71	6	59	67	67	65	21	24	8
Grey	61	-	71	52	58	20	19	12	11	56	50	61
Black	64	68	-	60	63	54	31	33	67	66	65	67
Brown	66	43	62	-	65	40	20	11	36	59	61	65
Yellow	5	57	75	66	-	48	60	57	54	19	18	3
Y-R	54	25	66	50	45	-	20	27	28	36	32	46
Red	51	15	49	21	50	15	-	12	18	37	40	49
R-B	64	17	44	8	60	31	13	-	26	51	54	66
Blue	52	9	68	36	53	21	23	15	-	56	52	59
B-G	15	53	71	62	12	35	37	47	54	-	2	11
Green	14	50	66	55	11	28	30	39	45	2	-	10
G-Y	6	54	73	66	3	43	57	51	56	12	12	-

Calculated NCS-values: 1200 (white), 5000 (grey), 8500 (black), 6040-Y50R (Brown), 1060-Y (yellow), 1070-Y50R (yellow-red), 1080-R (red), 2560-R50B (red-blue), 2070-B (blue), 1570-B50G (blue-green), 1070-G (green), and 1070-G50Y (green-yellow). n = 40

In the second study (Håkansson & Lindell, 1984) color combinations "simulating" actual commercially available equipments were used. The terminals/displays studied and simulated were: Alfascope, Apple, HP 120, HP 9816, IBM PC, PET 700 and Visual 300. 20 subjects judged their perceived reading efforts of texts displayed at random in the color combinations used in these terminals/displays. Each background color was also matched against white text.

With respect to the simulated color combinations and perceived reading efforts the results showed that:

1. No color combination was very good nor very bad

2. One color combination (IBM PC), was better than the majority and one (Alfascope) was worse.

For details please see Table 2.

Table 2. Judged perceived reading efforts, mean values, of simulated terminals/displays - color combinations

Terminals/displays			Mean 1)
Name	Text color	Background color	
IBM PC	"Ice blue" (0005-R80B)	"Midnight blue" (4040-R80B)	68 (69)
HP 9816	"Snow blue" (0502-B)	"Lead-grey" (7502-B)	59 (54)
Apple	Green (1070-G)	Black-green (8010-B30G)	54 (58)
HP 120	Green (1060-G)	Moss-green (8020-B70G)	53 (55)
Visual 300	"Dirty Yellow" (1070-Y)	Brown (7020-Y10R)	50 (59)
PET 700	Green-yellow (1080-G20Y)	Grey (6502-B)	47 (60)
Alfa scope	"Alfa yellow" (1080-Y40R)	"Redbrown" (7020-Y50R)	38 (55)

1) Mean values in ( ) refer to white text. n = 20

Context

In the third study (Andersson & Nilsson, 1984) the colors of the actual equipment were altered by placing frames in nine well defined colors in front of the terminal. In the experiment the context colors were selected at random. For each context ten different color combinations on text/background were shown at random.

Thus 20 subjects, students at the department of Computer Science at the University of Stockholm, all made 90 judgements of perceived reading efforts. The results showed that:

1. The close context is really important for the perceived reading effort.

2. The color of a terminal should be rather discrete. Best of all 90 combinations were black text on a white screen with a dark grey terminal, closely followed by the context colors black, white and light grey.

3. It is an advantage when the context color is the same as the color of either the color of the text or the background. The combination of context and text/background colors must match against each other. If they clashes the reading effort increases.

For details please see table 3.

Table 3. Judged perceived reading efforts, mean values for context colors and combinations of text and background colors. (high values = good combinations, low values = bad combinations).

Text/background	Context								
	Blue	Red	Yellow	Green	White	Black	Brown	Dark Grey	Light Grey
Black/White	64	62	59	60	64	66	62	68	64
Black/Yellow	51	49	56	47	47	55	55	50	54
Grey/Black	56	54	56	52	55	54	53	57	58
Blue/Black	53	53	54	49	50	55	55	52	53
Yellow/Grey	41	39	43	40	39	41	41	40	40
White/Red	33	28	28	33	33	30	31	33	30
Red/Green	17	15	16	20	15	15	16	15	17
Alfa scope[1]	41	42	37	39	40	37	44	41	46
IBM PC[2]	62	61	59	54	65	61	57	62	61
Facit[3]	53	56	51	53	51	53	55	55	57

1) "Alfa yellow" (1080-Y40R)/"red brown" (7020 - Y50R)

2) "Ice blue" (0005 - R80B)/"Midnight blue" (4040 - R80B)

3) "White green" (0070 - G10Y)/"Dark grey" (7502 - G)
n = 20

In the fourth study (Blomqvist & Zwierzak, 1984) the ambient lighting were altered. It was set at four well defined levels by using zero, one, two ot three nondisturbing fluorescent tube fittings simulating daylight (Luma Colorette). The windows in the laboratory was completely covered by black textile fabrics. In the zero level the room was totally dark except for the light emitted by the computer terminal. In each experiment the order of the four light levels, the different contexts, were selected at random. The NCS elementary colors were used for combinations of texts and background. Thus 20 subjects all made 120 judgements of their perceived reading efforts. The third ambient-light-level-part of the study was a repitition of the first study with respect to the 30 color combinations possible (See tables 4 and 1). The results showed that:

1. There was a good correlation with the previos findings.(0,98).

2. The ambient light level seem to be of no or very limited importance for the perceived reading effort. The differences between the mean values are within the variation at random.

For details regarding p.1 please see Table 4.

Table 4. Judged perceived reading efforts in "normal" lighting, mean values all subjects. (high values = good combinations, low values = bad combinations)

Background	Text					
	White	Black	Yellow	Red	Blue	Green
White	-	84	4	68	64	25
Black	71	-	66	42	63	70
Yellow	4	75	-	55	52	11
Red	52	46	43	-	14	37
Blue	53	73	54	19	-	48
Green	13	66	9	25	39	-

Calculated NCS-values: 1200 (white), 8500 (black), 1060-Y (yellow), 1080-R (red), 2070-B (blue), 1070-G (green). n = 20

Prints_outs

In the fifth study print outs from eight different printers were used (for samples please see table 5). These print outs were numbered and showed at random to 40 subjects who judged their perceived reading efforts of the different texts. The results showed that:

1. From eight tested print outs three cause little reading effort and thus are easy to read and quite acceptable.

2. Reading efforts of print outs are independent of the sex of the subjects.

For details regarding p. 1 please see Table 5.

It may be concluded from this study and the previous findings that at text presented in a good color combination on a visual display is easier to read than print outs from several printers.

Table 5. Judged perceived reading efforts of computer print outs, mean values all subjects. (high values = easy to read, low values = difficult to read)

Rank	Mean	Sample[1]
1	79	0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄÖÅabcdefghijklmnopqrstuvwxyzäöåñ
2	70	0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄÖAabcdefghijklmnopqrstuvwxyzäöäü
3	68	0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄÖÅabcdefghijklmnopqrstuvwxyzäöa½
4	55	0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄöAabcdefghijklmnopqrstuvwxyzäöäü
5	50	*0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄöAabcdefgnijklmnopqrstuvwxyzäöäü*
6	44	0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄöAabcdefghijklmnopqrstuvwxyzäöäü
7	43	0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZÄÖÅ abcdefghijklmnopqrstuvwxyzäöä
8	31	*0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZäöäabcdefghijklmnopqrstuvwxyzäöäü*

n = 40 1) In the experiment actual fullpage texts were used.

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